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TITLE: CONCEPTUAL DESIGN FOR AN AIR CORE 2 MEG-AMP REVERSED FIELD EXPERIMENT

AUTHOR(S): CHARLES F. HAMMER

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Los Alamos National Laboratory
Los Alamos, New Mexico 87545

CONCEPTUAL DESIGN FOR AN AIR CORE 2 MEG-AMP RLVERSED FIELD EXPERIMENT*

Charles F. Hammer
Reporting for the ZT-40U Conceptual Design Team

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ABSTRACT

The Los Alamos CTR Division is involved in the conceptual design of a next phase Reversed Field Pinch experiment. The paper will discuss, in general, some of the physics questions that the experiment will address. Also in more detail it will discuss the engineering parameters and the possible hardware design solutions.

The experiment is designed to produce a plasma current of about 2 MA which can be sustained for about 200 ms. The electrical energy for the system is provided by a large motor generator set. An inductive energy store is used to drive the magnetizing and poloidal field windings. A capacitor bank provides the energy for the toroidal field windings. The current in both circuits is maintained by using SCR controlled transformer rectifiers.

Introduction

During 1982 and part of 1983 the Los Alamos CTR-Division has been involved in the conceptual design of a 2 Meg-Amp, Air Core, Reversed Field Experiment (RFP) (Illustrated in Fig. 1), which is referred to as ZT-40U. This paper presents a summary of this work.[1]

During this period ZT-40M was operated as a physics experiment and provided the basis for much of the thinking that has gone into the design of ZT-40U. Findings from ZT-40M have resulted in a continuous evolution of the ZT-40U conceptual design. As an example of this is, the conceptual ZT-40U liner design does not incorporate a feature which allows repair or replacement of damaged liner sections without removing the entire liner. Experience from ZT-40M indicates that it would be desirable to be able to repair or replace portions of the liner in place. This means the conceptual ZT-40U liner design will probably have to be changed.

Also during this period of time the design of ZT-P, a small, aircore, engineering and physics RFP prototype, has approached completion. Its design incorporates many of the engineering features from ZT-40U. It will begin to address some physics issues such as the importance of a conducting shell to the stability of the plasma. ZT-P is now being constructed and should be operating by the summer of 1984.

Experiment Objectives

The experimental program for ZT-40U will address a number of scientific and technological issues listed below.

- Demonstrate and extend fundamental RFP physics.
- Achieve significant plasma energy solely through ohmic-heating currents.

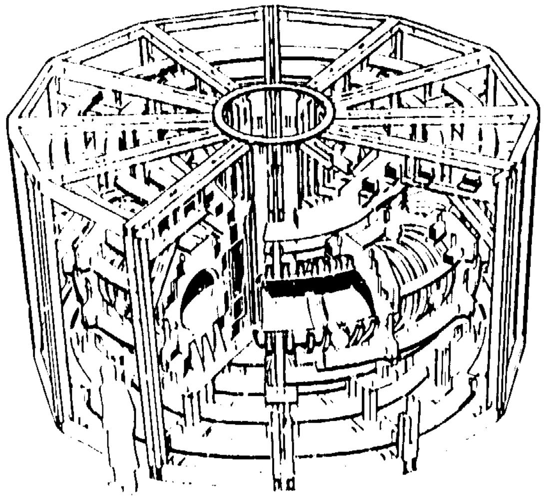

Fig. 1.

- Achieve and maintain betas of reactor interest.
- Demonstrate high-current-density operation.
- Control plasma wall interactions.
- Control R.F.P. magnetics related to equilibrium, wall stabilization, and allowable field errors.
- Obtain energy confinement time and plasma temperature scaling with density and plasma current.

Technological Objectives include:

- Extend limiter schemes, and examine poloidal and toroidal diverter schemes.
- Develop and test first-wall designs capable of reactor-like thermal wall loading ($5\ MW/m^2$).
- Examine startup methods. Determine the feasibility of ramping the current up after the RFP has been established.
- Examine means for steady-state current drive.

Machine Description

Torus Assembly

The vacuum liner and shell assembly (section shown in Fig. 2) is quite similar to that used on ZT-40M[2]. The liner is made of twelve Inconel 625 bellow sections which are joined together by wedge shaped cylindrical sections. The vacuum and diagnostic access ports are located in the joining sections. The shell is made of cast aluminum which is nominally 51 mm thick. The shell structure consists of 8 sand-cast sections which are precisely machined to the final dimensions. Extreme care will be taken in providing low resistance

* Work performed under the auspices of US DOE.

TABLE I

ZT-40U Descriptive Specification

Plasma Current	(MA)	2.0
Rise Time	(ms)	20
Flat-top Time	(ms)	200
Major Radius	(m)	2.15
Minor Radius	(m)	0.4
Vacuum Liner (Inconel 625) thickness (mm)		2.3
Possible wall loading (MW/m^2)		~1. to 5.
Shell (cast aluminum) thickness (mm)		50.8

at the conducting joints of the shell. The final shell assembly will have 2 vertical insulating joints and one horizontal break at the inside of the torus midplane.

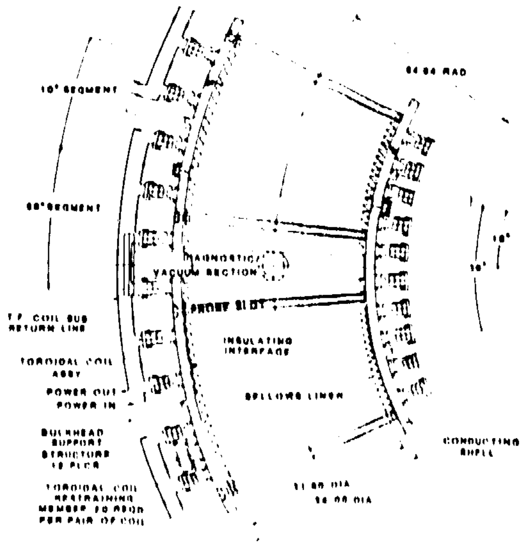

Figure 2.

Toroidal field coils

There are 72 toroidal field coil modules mounted uniformly on the torus located at 5° intervals. Each module consists of two adjacent coils with each coil making two complete turns around the torus which results in a total of 288 turns. Individual coils are made of thin laminated copper strips, wrapped with tape insulation which is applied just prior to installation on the coil form. The coil form is attached to shell prior to winding the coil. The coil can be wound in place because they are flexible and can be overlapped. Doing this reduces the total number of high current joints in the T.F. system which reduces the complexity.

Poloidal field coils

The Poloidal field system consists of magnetizing (M) and equilibrium (E) coil windings. There are 16 M coils (160 turns total) and 8 E coils (260 turns total) which are located as shown in Fig. 1. The coil assemblies are made using copper bar stock and a thermo setting plastic adhesive to hold the copper in place.

Each winding system is connected through a patch panel to the buss system to the respective energy systems. The patch panel is designed so that various series-parallel coil interconnections are possible.

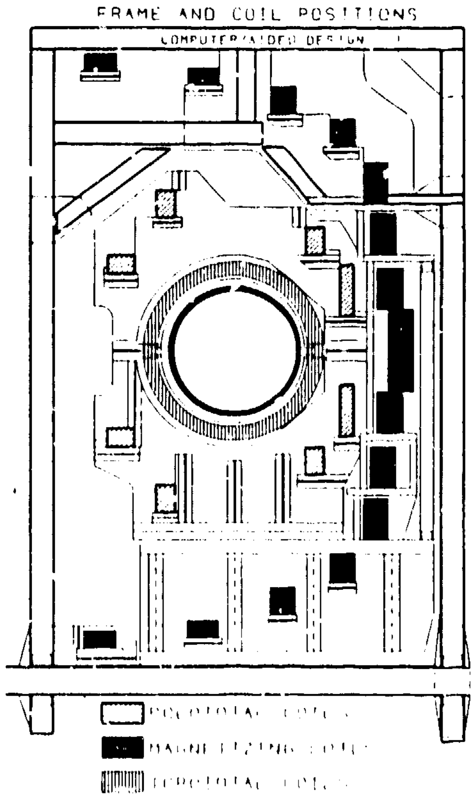

Figure 3.

Mechanical Support Structure

The torus assembly, magnetizing and equilibrium windings are supported and held in place by a mechanical structure which is fabricated of non-metallic, non-conducting materials. This structure is designed to carry the weight of this hardware, and also absorb the pulsed forces which are generated during the machine operation. The structure or bulkhead assemblies resemble the spokes of a wheel when viewed from above and include 12 bulkhead locations. This is illustrated in figure 1.

Energy Systems

The poloidal field coils are driven by an inductive energy storage system during start-up and the flat-top energy is supplied by a transformer-rectifier power supply (shown in Fig. 4). The toroidal field coils are driven by a capacitor bank during start up and the flat-top energy is also provided by a transformer-rectifier power supply (shown in Fig. 5). The energy for these systems will be supplied (as shown in Fig. 6) by a large motor-generator set, operating at near rated speed. The energy stored by the M-G-S will be transferred to the experiment as it slows to approximately 70% of rated speed.

An equilibrium control power supply is included which controls the E coil current required for equilibrium. The equilibrium system consists of a pulse width modulated, solid state, switching power supply, which is feedback controlled.

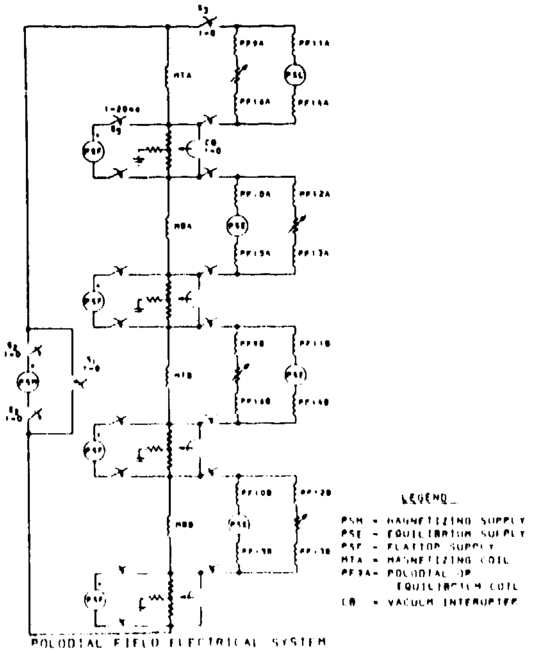

Figure 4.

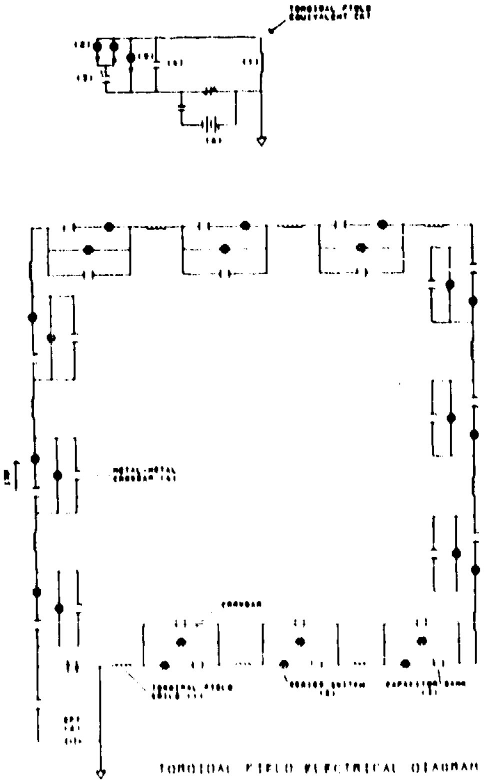

Figure 5.

Computers

The design will make extensive use of computer technology. The system will have a computer for each of the following functions: Experiment Control, Data Acquisition and Data Analysis. The computers will be linked by a high speed network and with the functional distribution, the network traffic can be kept to a minimum. The control computer will communicate with lower level subsystem computers by means of high speed links. The subsystem computers will run a common control program that carries out local control and monitoring functions under the direction of the control computer. In the event of a subsystem fault, the subsystem computer will take any immediate action required and then notify the main control computer.

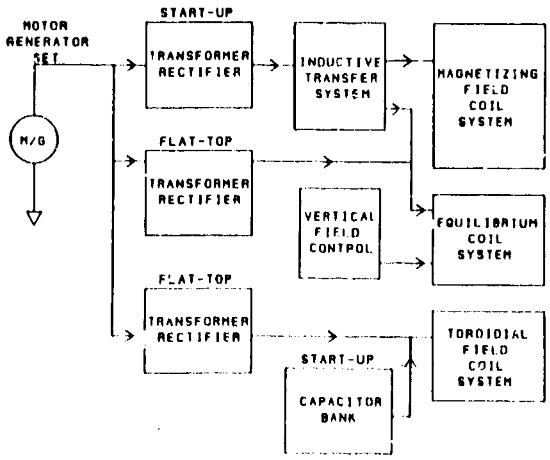

Figure 6.

Special Design Consideration

Low magnetic field errors in the plasma region and easy diagnostic access to the plasma region played a very large role in the design and location of coil systems. To further reduce field errors the structure for the experiment has been designed using non-magnetic, non-conducting materials. The mechanical structure of the machine is such that it can be taken apart in a modular fashion, which will facilitate the disassembly of the front end in the event of a component failure.

Diagnostic and vacuum ports are relatively large to allow good access to the vacuum region for diagnostic and vacuum pumping purposes. Additionally, the large ports are very desirable for the installation and removal of limiter hardware.

Other considerations

This summary does not begin to address all of the areas which were investigated as part of the ZT-40U design study. The following subjects have been examined in detail [1]; Magnetics, Diagnostics, Electromagnetic Compatibility (normal and fault conditions), Power Supplies, Switching Systems, Field Coil Design, Mechanical Structure, High Vacuum System, Shell and Liner Design, Limiter System, and Computer and Control System.

Acknowledgement for those who have contributed to this work is very difficult because of the large number of dedicated individuals involved. Rather than overlook any one, the acknowledgements go to all those who were involved with the ZT-40U design effort.

References

[1] P. Thullen, "ZT-40U: Conceptual Design of a 2 MA Reversed Field Pinch Experiment," Los Alamos National Laboratory report LA-UR-83-1375 (1983).

[2] R. S. Dike and J. N. Downing, "All Metal Vacuum Chamber for the ZT-40 Experiment," 9th Symposium on Engineering Problems of Fusion Research, 1981, pp. 1373-1377.